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Drainage of Farm Lands

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INTRODUCTION.

Throughout the eastern section of this State there is a growing demand for serviceable information concerning the drainage of farm lands. This bulletin is prepared to meet this demand, and to show the benefits to be derived from drainage; also the best methods and the cost of such work. It is hoped that the presentation of this simple and limited exposition of such an extensive subject, may be of service in the reclamation of the great areas of wet lands, now existent in this State.

On account of limited space, this bulletin will describe the construction of drainage outlets. A later bulletin will describe the theory and practice of tile drainage.

The author wishes to thank the following manufacturers of dredging machinery for photographs from which some of the following illustrations were made, and also for other valuable information: The Bucyrus Company, of South Milwaukee, Wis.; The F. C. Austin Drainage Excavator Company, of Chicago, Ill., and The Browning Manufacturing Company, of Cleveland, Ohio.

The attention of the reader is called to the diagram of the South Dakota drainage law. It is thought that this diagram will be of value to those seeking information on the legal procedure necessary to secure the construction of outlet drains and their sub-drains.

DRAINAGE REQUIRED.

The eastern half of the State of South Dakota, comprising the territory east of the Missouri river, was covered in the glacial period by a great sheet of ice. Gradually this ice moved southward, scouring and moulding the surface of the country as it passed along. The melting of the ice along the edges of this great glacier formed the valleys of the Missouri and the Sioux rivers. Thus, as a result of this great primeval force, we have a comparatively level area; traversed by the great river valleys of the James and Vermillion rivers. Upon close inspection, we find a large number of basins scattered over this area, and of an infinite variety as to size and shape; from the small "pot-holes" or basins, found all over this section of the State, and especially in its southern part, to the large lakes of Kingsbury and Codington counties.

During the seasons of melting snow and continued rainfall, occurring from early spring to early summer of each year, these basins are filled with water draining down from the neighboring watersheds. Not having any outlet, this water remains on the land until removed by evaporation or below the surface by the lowering of the water table of the sub-surface water. Thus are formed the great areas of swamp and marsh land, of which about 400,000 acres remain undrained. The deposition, for untold centuries, of silt and vegetable matter upon this low wet land, renders it highly fertile, and it only remains for suitable drainage to bring it under continuous cultivation.

The necessity and value of drainage are becoming better understood by both practical farmers and non-resident land owners, as time goes on. The up-to-date farmer realizes that it is an important element of scientific agriculture, and is making use of it to obtain the best results from land not possessing natural drainage. To properly construct an efficient drainage system, the progressive farmer desires to know how to plan for and carry out the work so that the cost will be well within the returns, which may be expected from the improvement. To this end, it is necessary that he have a clear and intelligent idea of the theory and practice of drainage.

THEORY OF DRAINAGE.

The soil is made up of very small particles of irregular shapes, varying size and different characteristics. These particles do not lie together so as to form a solid mass, but are separated by spaces, which in an ordinary soil, equal nearly one-half the volume. When water falls upon the surface, that which does not immediately run off, starts to percolate down through these spaces in the soil. This water descends until it meets the surface of the underground water, whose level it raises, unless some method of drainage is at hand to remove the surplus as it is added. When sufficient water has been added in this way, the level of the water table will rise above the surface and form a marsh, slough or lake. A soil whose intervening spaces are filled with water, is called a saturated or very wet soil. It is worthless except for the growth of aquatic plants. Now, if a means be provided for the removal of this water, such as by sub-soil or underground drainage, the water will move downwards through the spaces by the action of gravity. This will continue as long as the drainage acts to carry off the surplus water. A point will be reached usually near the level of the bottom of the drain, where the downward movement of the water will cease, and the new water table be established. As the water descends through the soil, a certain amount, usually about twenty per cent of all the water, remains behind and collects as a film over the surface of the particles of the soil. This water is called capillary water from the force which causes it. It furnishes the moisture necessary for the growth of vegetation and the proper production of plant food. The remaining space in the soil, not occupied by this useful water, is taken up by air, which is a vital element in the generation and propagation of vegetable life. Thus, since it is known that vegetation takes its nourishment from the soil in liquid form, a surplus of water in the soil will exclude the air, reduce the temperature, dilute the plant food and either retard or stop the growth of the plants.

In the western part of the State is often found an open, porous sub-soil of such nature that it gives free passage to the movement of surplus water, and thus natural drainage is provided. However, in the eastern section of the State, the sub-soil is usually

composed of a mixture of loam and clay underlaid with a fine clay, which is of a very retentive character and passes through very slowly, the gravity water coming from direct rainfall or by seepage from lands at a higher elevation. It is the purpose of artificial drainage to remove this excess gravity water and to thus provide the necessary air space in the soil to accompany the moisture remaining as suitable nourishment for the vegetation.

SURFACE AND SUB-SURFACE DRAINAGE.

The drainage of a soil may be effected in two ways: (a) surface drainage; (b) sub-surface drainage.

Surface drainage comprises the removal of surplus water from the surface of the land by means of open channels or ditches. These ditches, however, if of sufficient depth, may afford drainage for the sub-surface water and thus do double duty and be of greater value.

Sub-surface or under-drainage, consists in the removal of surplus gravity or sub-surface water by means of underground conduits, such as drain tile. The advantage and benefits to be derived from under-drainage are as follows:

(1) The retention on and near the surface of the fine, rich soil carried in solution by the water.

(2) The carriage into and through the soil of fertilizing material, valuable to the nourishment of the roots of plants.

(3) The rendering of the soil more porous, open and workable, thus adding to its nourishing power and accessibility for root penetration.

(4) The soil is always ready for cultivation during the growing season and very responsive and productive as a result of such cultivation.

(5) The thawing out of the ground earlier in the spring and the advancement of the planting season thereby.

(6) The enriching of the surface soil and the addition of sub-surface nourishment reduce the effects of a drought.

OPEN CHANNELS OR DRAINS.

The drainage of large level sections of land, such as the submerged areas on the bench, level and the bottom lands along the river valleys, require the construction of large open ditches.

These should follow, as nearly as practicable, the natural course of the drainage of the land, which is usually a dry run or "draw," or a flowing water course. Since the slope of the land is usually so slight, these water courses are shallow and winding in their course, and must be enlarged in size and straightened in alignment in order to provide suitable capacity and discharge of the water drained into them.

Open drains are often an inconvenience in that they divide a section of land into irregularly shaped plots, and also take up land which cannot be devoted to any other purpose. However, these ditches are necessary to provide sufficient outlets for large quantities of water, which may be discharged into them from tributary drains and the outlet mains of tile-drain systems. Ditches may be of various shapes and sizes, depending on the amount of water to be carried, the character of the soil, shape of the ditch, method of construction, etc. The side slopes in clay and loam may be made at an angle of forty-five degrees with a horizontal or a slope of one to one. If sand or gravel, this slope must be increased to that of one and one-half horizontal to one vertical, and in the case of very loose running soil, to a slope of two horizontal to one vertical.

CONSTRUCTION OF OPEN DITCHES.

The method of excavating an open ditch depends upon a number of conditions, peculiar to each particular case. The size and character of the drain, the character and condition of the soil, the location of the proposed work and the availability of labor and machinery, all go to determine to a greater or less extent, the method and appliances to be used in the construction. The following methods are commonly employed:

(a) By team and scraper.
(b) By capstan plow.
(c) By floating dipper dredge.
(d) By dry land dredge with scraper buckets.
(e) By dry land dredge of elevator type.

(a) This common method of moving earth can only be used where the ditch has rather flat sides slopes, is not deep and runs through dry soil. For small ditches, from three to five feet in

depth, and having a bottom width of not less than four feet, such as are often constructed as an outlet drain for several adjacent farms, this method is practicable. The farmers interested may co-operate and do the work themselves or let the contract to some disinterested farmer. The cost of excavating a drain by this method, under ordinary conditions, will vary from ten to sixteen cents per cubic yard.

(b) In recent years, the construction of small outlet drains and laterals through flat, wet land, is being made largely by the so-called capstan plows. It is an immense plow mounted on trucks and excavates by cutting straight through the soil and throwing the earth out and away to each side. As the plow moves ahead, the earth thrown up is pushed three or more feet away from the sides of the excavation by large wings, projecting backward and outward from the rear of the plow. The excavated material is thus left in even, continuous banks on each side. The depth of the ditch may be varied one foot by means of a large screw which raises and lowers the plow on the trucks.

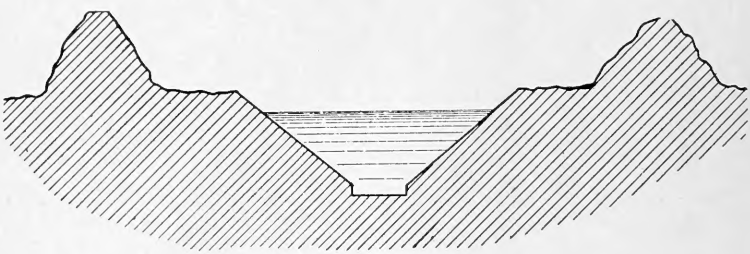

Fig. 1 - Section of Capstan Plow Ditch

The machine is moved forward by two capstans, each anchored ahead of the plow and connected to it by wire cables or ropes. A team of horses is connected to and turns each capstan. There are two sizes of these excavators generally used in this and neighboring States; one which makes a ditch two feet wide on the bottom, two to three feet in depth and six to eight feet on top, and another larger machine which makes a ditch having a bottom width of three feet, a depth of from three to four feet and a top width of from nine to eleven feet. The ditch is usually clean cut

Fig. 2. A 3½-yard Dredge Constructing a Drain in Illinois.

and has side slopes of nearly one to one. Fig. 1 shows a cross-section of a typical ditch. Contractors usually do the work for from eighty cents to one dollar and a half per rod, depending on the size of the ditch. Where the soil is wet and the surface has a uniform slope, this method can be satisfactorily used for constructing small ditches. However, for uneven ground and deep ditches, it fails in being unable to excavate the bottom of the ditch to a true and uniform grade and the resulting drain is too shallow for under-drainage.

(c) Where large areas of flat, low, wet lands are to be drained, such as we have along the river bottoms in the southern and eastern counties, and in the so-called dry lake beds in Clark, Kingsbury and Codington counties in this State; the construction of the large outlet channels is most economically and readily made with the floating dredge. This consists of a rectangular shaped hull or boat built of heavy timbers and carrying in the rear the boiler and swinging and hoisting engines. On the front end of the boat is the boom or crane carrying the dipper and dipper handle. The dipper on the lower end of the dipper handle

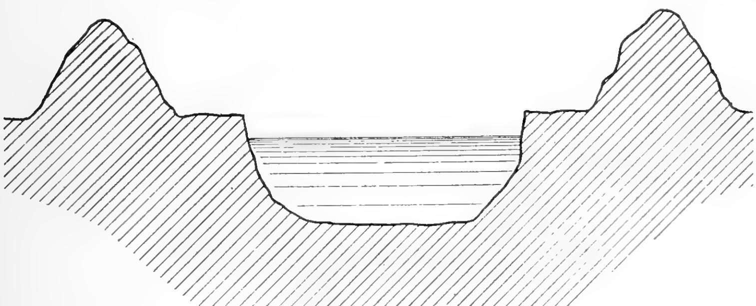

Fig 3 - Section of Ditch constructed by Floating Dipper Dredge.

is raised and lowered by the motion of the dipper handle between the two sections of the boom, which is swung from side to side by the swinging engines. The dipper has a capacity of from three-quarters to two and one-half cubic yards, depending on the size of the dredge. Spuds or anchors, one on each side near

front end of the boat and one in the middle of the rear end, hold the boat steady while the boom is being swung about. Such a floating dredge begins work at the upper end of the ditch and requires sufficient water to float it as it excavates along on its course down the ditch line. A three and one-half yard machine at work in Illinois is shown in Fig. 2. This machine will excavate ditches varying in width from fifteen to seventy-five feet, and in depth from three to fifteen feet. The section of ditch which a floating dipper dredge will excavate is somewhat the form of the letter U as shown in Fig. 3. It is impossible for an excavating machine of this type to make side slopes less than one-half horizontal to one vertical and true and uniform. Neither can it dig true to grade. The sides will be more or less rough and irregular and the grade of the bottom of the ditch will vary from three to twelve inches below the true grade. The contractors usually excavate the ditch larger and deeper than required so that when the low places are filled in by the deposition of silt and fine debris, the ditch will acquire a uniform cross-section of at least the capacity required by the specifications. The form of the ditch after a few seasons of erosion and weathering is shown in Fig. 4. The cost of excavation depends on the amount of yardage and

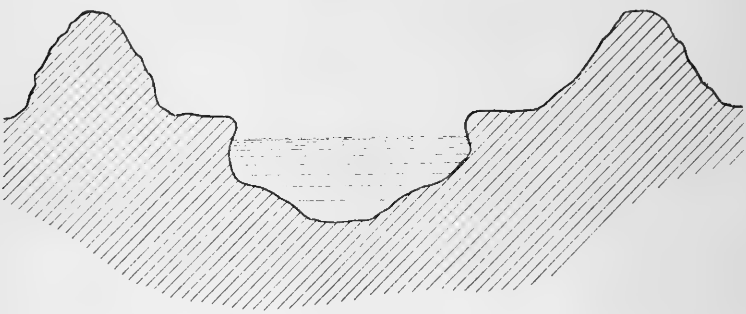

Fig 4 Section of Floating Dredge Ditch after erosion and weathering

conditions, and varies from seven to fifteen cents per cubic yard.

(d) The scraper dredge of the Page bucket type consists of a hull or boat with machinery similar to that used on a floating dredge. On the front end of the boat are two booms or cranes,

Fig. 5. A Drag-line Bucket Dredge at Work.

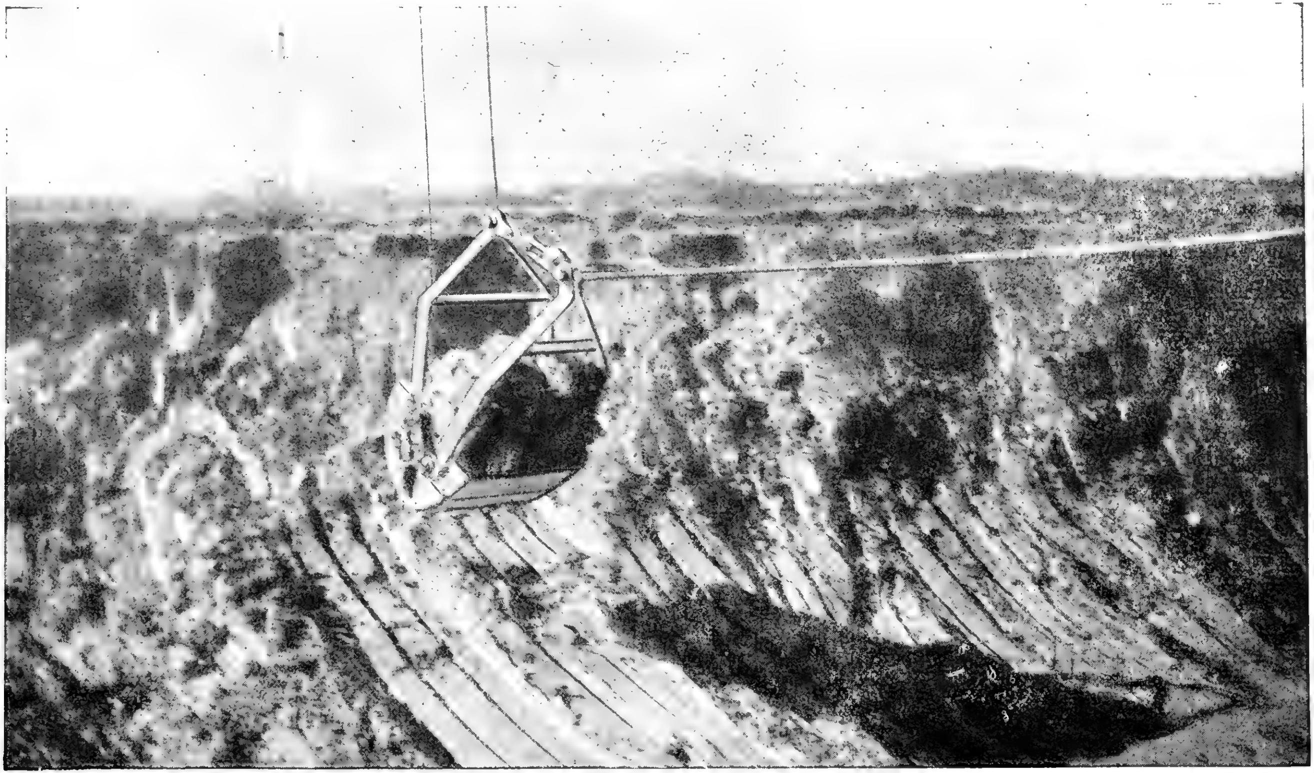

Fig. 6. A Drag-line Bucket and Its Excavated Ditch.

one mounted at each corner and, in this case, the bucket or scraper moves along the boom and draws the excavated material out of the ditch prism towards the boat. The boom is then swung out of the ditch line and the material deposited in a spoil bank along the sides. One scraper is usually excavating from the ditch prism, while the other is depositing its load on the spoil bank. The dredge begins operations at the lower end of the ditch and works away from the excavation. The boat moves along on rollers which run on large planks. It can dig efficiently in firm and hard material, but work in wet and marshy soil requires extensive and expensive blocking and bridging to support the boat. Also where the ground surface is very uneven, the preparation of the roadway for the boat is a source of much trouble and expense. This type of machine, therefore, is most useful and efficient on flat areas which are fairly dry and firm where it can make a ditch with clean, uniform sides and approximately true to grade. Where the soil is wet and soft, a floating dredge would be the most economical and efficient type of excavator. There are many land-locked lakes or basins in this State, where the construction of an outlet will require the excavation of ditches over twenty feet in depth. This will require a scraper dredge with an especially long crane. Such a machine is shown in Fig. 5. The machine is pivoted so as to revolve and move freely in any position. The boom or crane varies from seventy-five to one hundred feet in length, and is made of a steel framework. The steel scraper can remove from two to four cubic yards of material at a time at a depth of fifty feet below the surface and then deposit it along the sides of the ditch to a height of about thirty-five feet above the surface. In Fig. 6 is shown the scraper or so-called drag line bucket excavating a large ditch. This machine is very powerful and can dig in nearly any kind of soil and under very adverse conditions.

(e) In the last few years, a type of scraper traction dredge built on the elevator principle has come into general use. Two scrapers connected together and facing in opposite directions, move along a guide frame which is set transversely to the line of the ditch and forms the front part of the machine. The scrapers move back and forth from one end of the guide frame to the other and each time excavate a thin slice of material from the ditch

prism. As the earth is removed by the scrapers, the frame is automatically lowered until the proper depth is reached. The dredge moves along on a track composed of a rail set on each side of the ditch. It can operate successfully in any but very wet soil, where the labor and expense of constructing a suitable track would render its use impracticable. The ditch constructed by such a machine has true, clean and smooth sides and has a uniform grade, as is shown in Fig. 7; the ditch is nearly mechanically

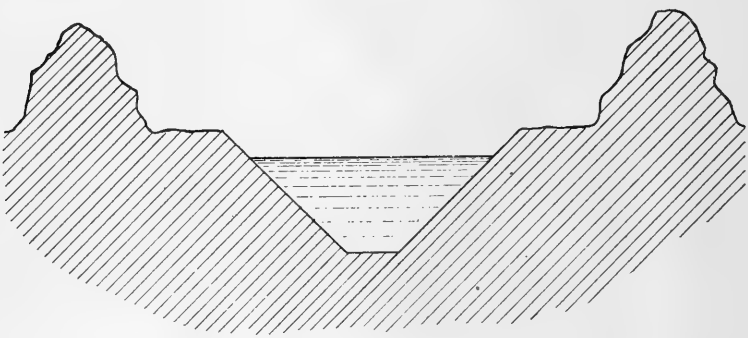

Fig. 7 - Section of Ditch constructed by Dry Land Machine

perfect. Fig. 8 shows one of the latest and best types of this class of dredge, which is beginning the construction of a wide bottom ditch. A similar machine, but excavating a narrow bottom ditch, is shown in Fig. 9.

An excavator of this type works most efficiently upon dry soil and where the area to be drained is flat. Work can be done on wet land by starting at the outlet and digging up stream, although the cost and labor of planking often renders this uneconomical. Such a machine is not practical in a heavily timbered country or where large boulders and ledges of rock abound.

THE SELECTION OF A DREDGE.

The cost of construction of a dredge varies from $5,000 to $10,000, depending upon its size and capacity. It is clearly evident that a ditch must be of a sufficient size to warrant the use of such a machine in its excavation. Where the ditch has a length

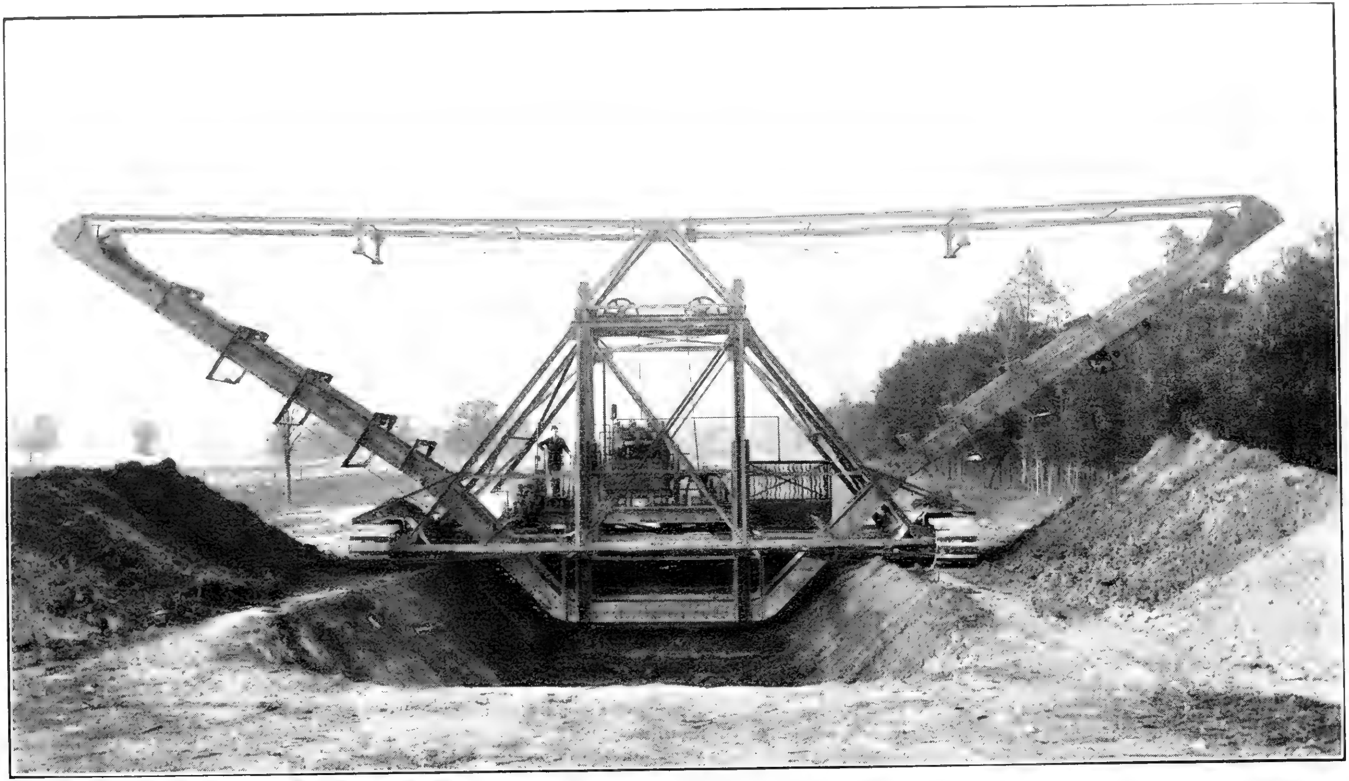

Fig. 8. A Dry Land Dredge or Excavator Constructing a Wide Bottom Drainage Ditch.

Fig. 9. A Dry Land Dredge or Excavator Constructing a Narrow Bottom Drainage Ditch.

of less than three miles, and a total excavation of less than 50,000 cubic yards, a dredge cannot be economically used.

The construction of small ditches, having a width of less than fifteen feet on the surface, should be made with a dry land or traction machine of the type that will excavate the section of the ditch true and even, and its bottom true to grade. This is essential in small ditches, as they are apt to fill up with silt, debris and growing vegetation, and a high velocity is necessary to keep them flushed out. Such a flushing velocity can best be secured by constructing the ditches true as to form and grade. Where the open ditches are large, wide and deep, it is not so essential to construct them true in form and accurately to grade. The U form of ditch constructed by a floating dipper dredge is often irregular in shape and the grade of the bottom varying. However, the velocity of the flow is usually enough to gradually fill up the depressions and cut down the projections so that the ditch, after a few years, assumes a regular and uniform shape. However, a ditch constructed by a machine of the scraper type, true to cross-section and grade, will offer less resistance to the flow of the water and will require much less maintenance than a ditch constructed by a floating dredge.

The essential consideration in the construction of any open ditch is to secure sufficient depth. A shallow ditch will cause the water flowing through it to move with a small velocity, and during the dry seasons, the shallow depth and low resulting velocity cause deposition of silt and debris and, in time, the ditch fills up. Hence a shallow ditch soon after its construction becomes useless for the rapid and complete removal of even surface water. An open drain must have a depth of not less than five feet in order to serve as an under-drain and remove the sub-surface water. The writer has known of cases where a deep open drain has dried out marshes and swamps through which it passed, for a distance of more than a mile on each side of its banks. The velocity and discharge of a ditch vary with the depth and grade. The grade should be as large as possible, consistent with the securing of a velocity not greater than that which would erode the banks of the ditch. In loam and clay soil, such as is generally found in the eastern part of this State, the maximum allowable velocity is about six feet per second. Where a higher velocity is necessary,

the banks should be rip-rapped, concreted or otherwise protected to prevent serious erosion. As the depth of water in a ditch increases, its velocity increases, due to the static head thus gained. Thus, if the depth of water in a ditch be increased from one foot to eight, the velocity will be doubled.

To illustrate the construction of a large public drainage outlet, the following description of the Clay Creek Ditch is given.

THE CLAY CREEK DRAINAGE DITCH.

The location of this drain is a great flat area of bottom land, lying between the Missouri and James rivers on the south and west and the bluffs or table land on the north and east, in Yankton and Clay counties of this State. This territory of about 35,000 acres has a slope to the south and east of about one foot per mile.

The natural drain of this area is a small, sluggish stream known as Clay creek, which has never been sufficient to properly drain the land. In 1887 the farmers of this district co-operated and constructed a small ditch, which used the creek as a basis and in as nearly a straight line as practicable, followed the natural drainage basin to a point near the outlet of the creek into the Vermillion river. This ditch, however, was constructed too small in size, and during the past twenty years has been gradually filling up with fine earth, debris and growth of vegetation, so that for many years past it has been useless. During the early part of the year 1904, a petition from the land owners of this territory was sent to the Department of Drainage Investigations of the United States Department of Agriculture, resulting in a preliminary survey which was made by a party from this department of the government service in August of that year. The results of the survey were embodied in a report which showed clearly and conclusively that this broad valley could be satisfactorily drained by means of ditches of sufficient size. After considerable discussion and further preliminary engineering work, a majority of the land owners of the district finally agreed upon definite action, and under the State drainage law, active proceedings were begun, under the jurisdiction of the boards of county commissioners of Clay and Yankton counties, acting conjointly; in the latter part of the year 1907. In February, 1908, the con-

Fig. 10. View of Clay Creek Ditch, Clay and Yankton Counties, South Dakota.

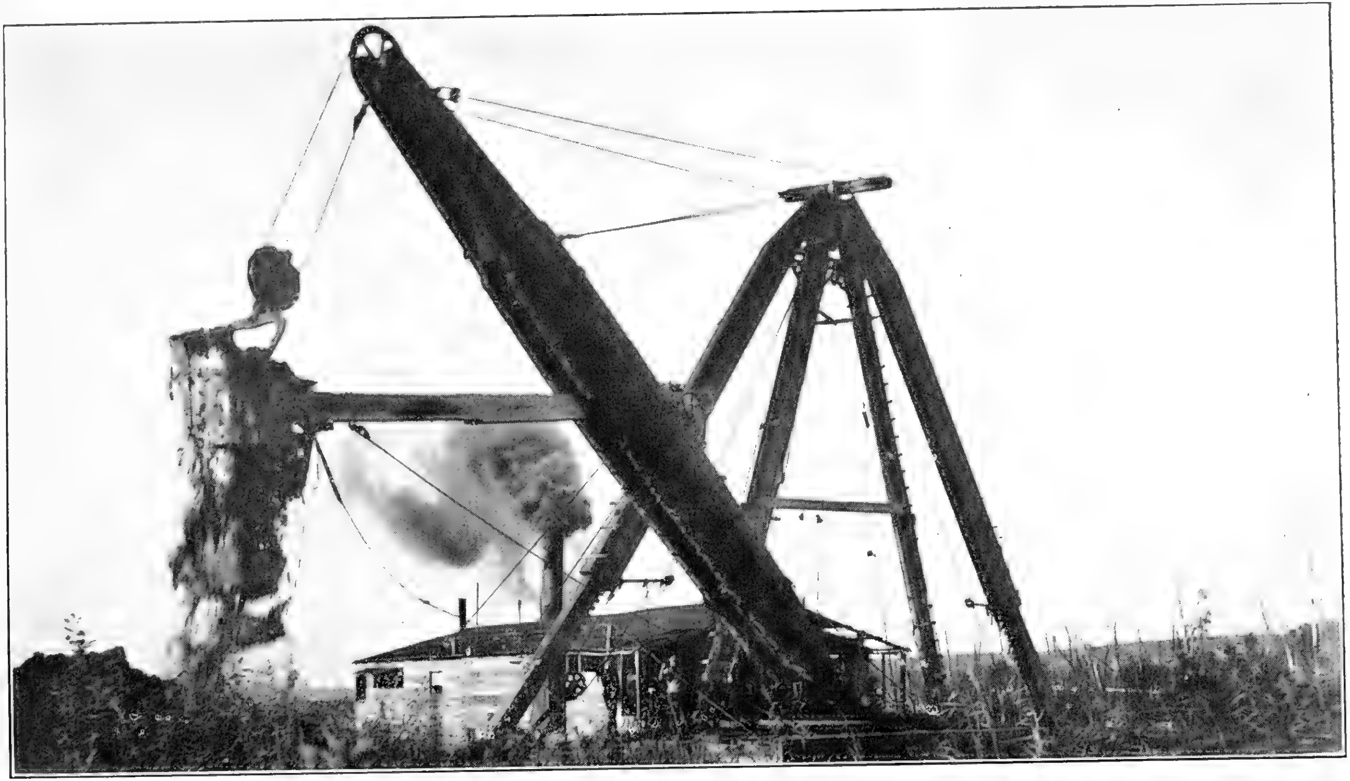

Fig. 11. View of Clay Creek Ditch, Clay and Yankton Counties, South Dakota —Dredge in Operation.

tract for the construction of the ditch was let to the Pollard & Campbell Dredging Company, of Omaha, Neb. During May and part of June, 1908, the writer, assisted by two of his students, made the location survey and designed the ten steel bridges for the road crossings.

The contractors began the erection of two floating dipper dredges about the middle of March, 1908. One was erected at the head of the ditch and the other about half way down the ditch line. The material was shipped by railroad to the nearest station and hauled by wagon to the site, where it was erected on the banks of the creek by a force of about eight men to a dredge. The lower dredge had a larger boat or hull and a longer boom than the upper, on account of having the larger end of the ditch to excavate, but the dippers on both dredges had a capacity of one and three-quarters cubic yards. House boats were constructed first before the erection of the dredges and were used throughout the entire work as homes for the men employed on the dredges. These were large, rectangular, flat bottom and two-story boats. The lower story served as a dining room, kitchen and storage room, while the upper story served as a bed room. Fig. 10 shows one of the house boats used on this work. The upper dredge began actual excavation during the latter part of July, 1908, and worked steadily until the early part of January, 1909, when the severity of the cold weather prevented further operations. The lower dredge, on account of delays in its construction, lack of water, etc., did not begin operations until the middle of September, 1908, and shut down for the season at the same time that the upper dredge did. Operations were again resumed by both machines during April, 1909, and the ditch was finally completed in January, 1910. Each dredge was run by two shifts of five men each, working twelve hours in each shift, with regular intervals for meals. While one shift worked the other slept on the house boat. Fig. 11 shows one of the dredges in operation. Sundays were spent in general repairs on the dredge and for rest and recreation. Six tons of coal per day, on the average, were necessary to feed the boilers for the necessary production of the steam power. While working uniformly and without serious accidents or delays, each dredge excavated 60,000 cubic yards each month. The ditch has a length of slightly more than six-

teen and a half miles and a bottom grade averaging about one and one-half feet per mile. The cross-section varies uniformly from beginning to the end; at the beginning the width at the bottom is about thirty feet and thirty-eight feet at the top, with a depth of about nine feet; while at the end the width at the bottom is about forty-two feet, and at the top about fifty-six feet; with a depth of about thirteen feet. This gives a trapezoidal cross section with side slopes of about one-half to one. Fig. 10 shows a typical view of the completed ditch. The average velocity of the water flowing through the ditch when the latter is about three-quarters full, is approximately four feet per second, or nearly two and three-quarters miles per hour. This is sufficient to ensure the proper flushing out of the ditch and, on the other hand, not large enough to erode the banks.

The cost of excavation was eight cents per cubic yard, and as 1,071,674 cubic yards were taken out by the dredges, this means a total cost of $85,734.00. Legal, engineering and incidental expenses connected with the proceeding brought the average cost per acre up to about $12.00.

Already, at the time of writing this bulletin (March, 1910), the indications are that this ditch will successfully furnish a direct drainage outlet for 35,000 acres of low, wet land, and indirectly drain about 40,000 acres more lying to the north on the table land in the northern part of Clay county. Thus has been completed the first step towards the reclamation of a vast area of formerly low, wet, and practically useless farm land, which, by the construction of suitable laterals and sub-drains, can be brought into condition for intensive cultivation.

PUBLIC DRAINAGE PROCEDURE.

The drainage of a farm or plot of ground by one interest or person can be done independently and at the pleasure of the owner. However, if we have a number of such farms whose drainage systems must have outlets, then the matter becomes one of co-operation and, therefore, of public concern. In order to facilitate the legal and just co-operation of land owners in the construction of a common outlet drain, this State has through its legislature, formed a drainage law. The following are the steps to be taken to secure the construction of a drain under the State law:

1st. A petition for a drain is filed in the office of the county auditor.

2d. The board of county commissioners acts upon the petition, views the proposed route with the State engineer, and if deemed advisable, orders an examination and survey made by a competent engineer.

3d. Examination and survey made by engineer who submits plans, report and estimate to the board of county commissioners.

4th. The board of county commissioners considers the engineer's report and supplementary report thereon from the State engineer. The county auditor advertises for a public hearing.

5th. Public hearing at which the board of county commissioners listens to the objections of land owners and grants or rejects the petition; thus rejecting or establishing the drain. If the petition is granted damages are determined upon and an engineer appointed to make final survey and plans and specifications for the drain.

6th. Public hearing at which benefits are equalized and steps taken to assess cost of work to the district to be benefited by the drain.

7th. At a public meeting of the board of county commissioners, bids for the construction of the drain are received, opened and considered. The contract is usually awarded to the lowest responsible bidder.

8th. A suitable method of financing the work is determined upon by the board of county commissioners. If necessary, bonds are issued and either placed with some bonding house or turned over directly to the contractor in payment for his work.

9th. The construction of the ditch and the final acceptance by the board of county commissioners on the recommendation of the engineer.

10th. The construction of laterals, if necessary, to furnish complete drainage for the district.

11th. Maintenance of the construction work.

Fig. 12 is a diagram of the South Dakota Drainage Law, showing the procedure necessary for co-operative drainage.

THE BENEFITS RESULTING FROM DRAINAGE.

"The soil is the farmer's best capital." He has come into his ownership by various means: inheritance, gift, or most likely, through the medium of exchange. He must depend upon it entirely for his future sustenance and welfare. It is clear that his success and prosperity depend upon the intelligence and industry which he exercises in the disposal and development of this capital.

There was a time about a couple of centuries ago when the farmer cultivated only in a crude, unintelligent way that part of his land most suitable for his various crops. Now, however, with the wonderfully rapid development of this country, land is becoming scarce and more valuable, and these great areas of undesirable and neglected land must be used. Every acre of such land in an untilled condition, means to the farmer to-day, just so much dormant, unproductive capital; every year during which it remains unproductive, it represents to the land owner a loss of taxes and the interest on his money invested.

A large, swampy piece of land is a blot on the landscape, a source of ill health, and perhaps of calamity to the people in the adjacent communities. This has been well illustrated in the southeastern part of this State, during the last two years, by the epidemic of anthrax. The farmers of Clay and Yankton counties have lost a large number of valuable horses and cattle which represents the loss of thousands of dollars. If this same money had been wisely expended years ago in suitable drainage, this calamity could have been averted. These low, wet, swampy areas are ideal breeding places for germs and their carriers of the most malignant and destructive character.

In the early part of this bulletin it was pointed out that the large sections of land throughout the eastern half of this State requiring drainage were natural basins or low, swampy land, lying on the table land or the great stretches of so-called bottom lands lying in the river valleys. Lower levels of this character of land are usually covered with a thick growth of marsh grass, reeds, cane and rushes; while the higher levels are generally used for pasture or hay land. However, on account of periodical overflows, these higher areas are often rendered useless even for the

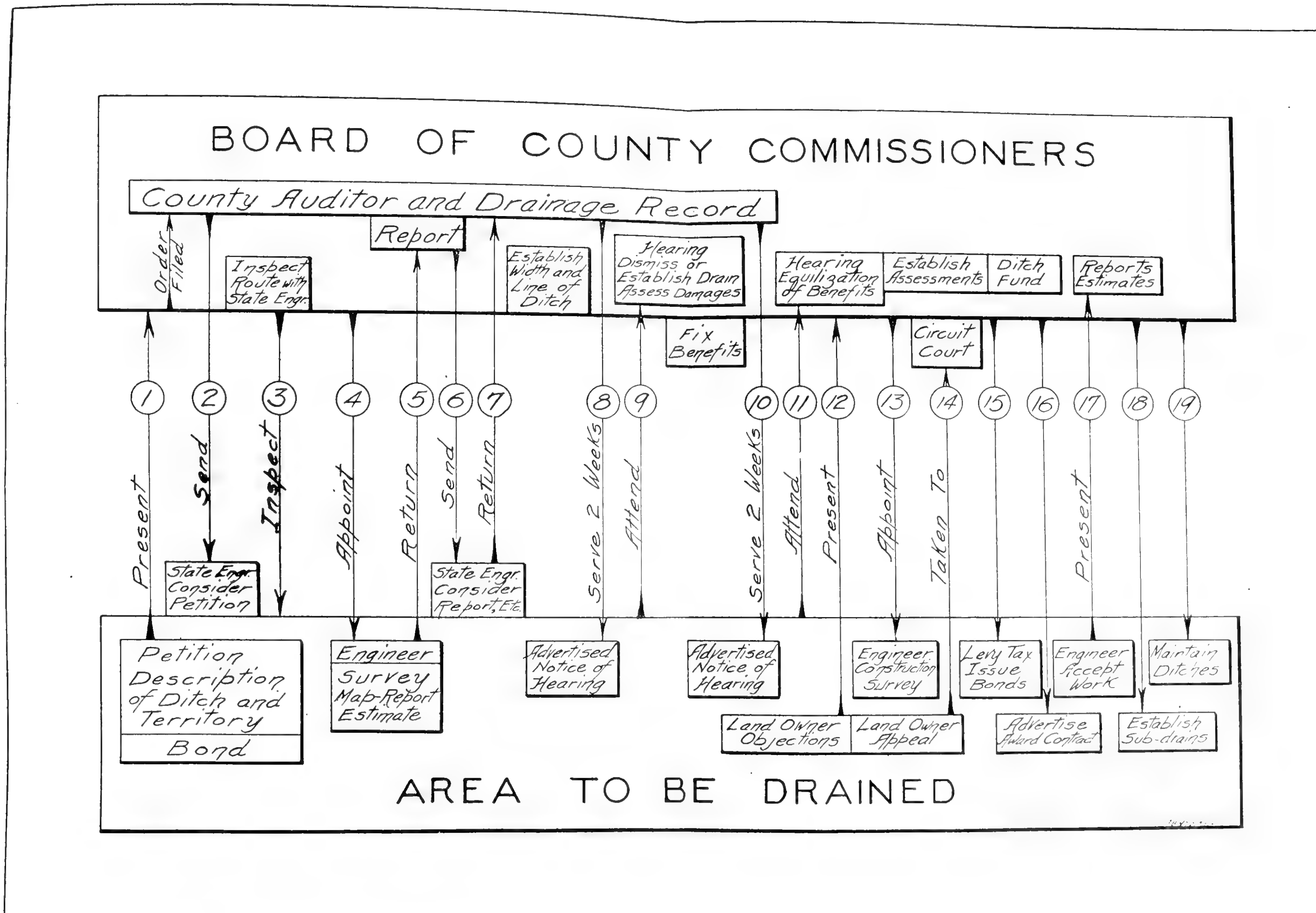

Fig. 12 Diagram showing the Procedure necessary in order to secure Co-operative Drainage under the Law of South Dakota

raising of hay crops. It is a well known fact that all of this low, wet land is of a highly fertile nature, there being a surface soil of rich loam of varying depth from three to six feet, and underlaid by a sub-soil. As has been suggested already under "Theory of Drainage," it is absolutely necessary to remove the surplus water from these level and wet lands in order that germination and the proper growth of vegetation may take place. It is just as necessary that the plant life shall have opportunity to breathe, as it is that human beings may be provided with necessary air for complete respiration. Every farmer also knows that his land must be thoroughly dry in order that he may have suitable access to it with his machinery for seeding, cultivating and harvesting.

I do not believe that there is a single farmer or land owner in this State, who would not agree with the writer in the statement that these low, wet lands are the most fertile of any in this great and prosperous commonwealth and should be properly drained. The only reason for hesitation in the prosecution of such work is the lack of past experience and present knowledge concerning this character of land improvement. However, this drainage work is not new and untried, as is shown by the great work done in the past to reclaim the fens of England, the marshes of Holland, the swamps of southern Italy and the great areas in Illinois, Minnesota, Louisiana, Arkansas, Iowa, and many other of the States of our nation. It is certainly just as feasible and practicable to drain 400,000 acres of wet, swampy land in South Dakota, as it is to build roads or make any other necessary improvements in the community.

The engineering problems connected with drainage are usually simple in character. Most of the areas needing drainage lie several feet above the mean low water level of some natural water course, which can be straightened, widened or deepened to afford sufficient outlet. In some cases it may be necessary to build levees or dykes to prevent the overflow of natural water coures.

The most important consideration as regards drainage to the farmer who has such improvement under consideration, is the matter of the cost of the proposed work. He desires to know whether the results to be derived from the drain will pay for the expense involved, and as a matter of business sense, has the right to know this before beginning the actual work. For such infor-

mation, let us consider the results of similar work in this and neighboring States. Where large areas of swamp lands have been thoroughly drained by open ditches and tile drains, the cost varies from six to thirty-five dollars per acre, while in places where tile drainage is not required, the cost will average about eight dollars per acre. From a thorough investigation of the cost of this work throughout the country, it would seem that a cost of twenty dollars per acre would be a safe average estimate for a complete and thorough drainage of the low, wet lands of this State. The market value of such land varies from ten to forty dollars per acre, depending upon the location and character of drainage, with an average value of about twenty-five dollars per acre. Similar lands in neighboring States, when thoroughly and properly drained, have sold for from sixty to a hundred and fifty dollars per acre, and when near large cities, have sold for as high as four hundred dollars per acre.

Now, let us consider as to whether it will pay the people of South Dakota to drain over 400,000 acres of low, wet land.

Cash value, after thorough drainage at $60.00 per acre		$24,000,000
Present value of this land at $25.00 per acre	$10,000,000	
Cost of drainage at $20.00 per acre	8,000,000	
Total value of land and cost of drainage		18,000,000
Net increase in value due to drainage		$ 6,000,000

Thus it will be seen that by drainage, the State would be enriched by $6,000,000, and each farmer benefited has at once increased his capital stock by an amount equivalent to fifteen dollars an acre. This increase would be immediate, while past experience in other States show us that future and larger increases in the value of land would quickly follow its improvement. These figures are not imaginary or mere guess work, but are based on results obtained in all sections of this country where drainage has been carried on. There are several cases in the southeastern part of this State where a complete drainage of the land has, within one year, enhanced its value from seventy to one hundred per cent.

The early work in this State has often times been improperly planned and poorly constructed, and as a result affords inadequate and incomplete drainage. This means a loss of time and money which is entirely unnecessary and hard to estimate. The boards of county commissioners of the various counties of this State where drainage is necessary, should not be content with the services of a surveyor unless he is a competent man with several years' experience in this class of engineering work. The services of a competent engineer should always be secured, and preferably a man with good experience in this particular class of work, in order that the county board may derive suitable and valuable information from him concerning the proper design and construction of the proposed drain, the proper damages to be allowed and suitable assessments to be made.

The faculty of the College of Engineering of the University desires to be of service to the people of the State. In this spirit this bulletin has been published and distributed. Anyone desiring information on engineering matters is invited to direct their inquiries to the Dean of the College, L. E. Akeley; Professor of Mechanical Engineering, M. W. Davidson; or Professor of Civil Engineering, A. B. McDaniel.

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